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Characterizing *Shorea robusta* communities in the part of Indian Terai landscape

V. S. Chitale • M. D. Behera • S. Matin • P. S. Roy • V. K. Sinha

Abstract：*Shorea robusta* Gaertn. f. (Sal) is one of the important tim-ber-yielding plants in India, which dominates the vegetation of Terai landscape of Uttar Pradesh state in India forming various communities based on its associations. The present study deals with delineation, map-ping and characterization of various communities of Sal (*Shorea robusta*) forests in Terai landscape of Uttar Pradesh, India ranging across over 16 districts. Field survey and visual interpretation based forest vegetation type classification and mapping was carried out as part of the project entitled 'Biodiversity characterization at landscape level using remote sensing and GIS'. Indian Remote Sensing-P6 (Resourcesat-1) Linear Imaging Self Scanner-III satellite data was used during the study. The total area covered by different Sal forests was found to be approximately 2256.77 km^2. Sal communities were identified and characterized based on their spectral properties, physiognomy and phytosociological charac-teristics. Following nine Sal communities were identified, delineated and mapped with reasonable accuracy *viz.*, *Chandar*, *Damar*, dry plains, moist plains, western alluvium, western alluvium plains, mixed moist deciduous, mixed dry deciduous and *Siwalik*. It is evident from the area estimates that mixed moist deciduous Sal is the most dominant commu-nity in the region covering around (1613.90 km^2), other major communi-ties were found as western alluvium plains Sal (362.44 km^2), mixed dry deciduous Sal (362.44 km^2) and dry plains Sal (107.71 km^2). The Terai landscape of Uttar Pradesh faces tremendous anthropogenic pressure leading to deterioration of the forests. Community level information could be used monitoring the status as well as for micro level conserva-tion and planning of the Sal forests in Terai Landscape of Uttar Pradesh.

Keywords: Vegetation mapping, LISS III, Forest management, Micro level Conservation

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Introduction

Shorea robusta is one of the major timber-yielding plants in India, known for its superior quality wood (Satya et al. 2005). The plant is native to south Asia and belongs to family Diptero-carpaceae (Ashton 1998). Its range extends from Myanmar in the east to Bangladesh, Nepal and India in the west. In India, it cov-ers nearly 13.3% of the forested landscape and ranges from the east (Assam, West Bengal, Orissa and Jharkhand) upto the northern end of India (Uttar Pradesh, Uttarakhand and Shivalik Hills in Haryana); the range also extends through the eastern Ghats and to the eastern Vindhyan and Satpura ranges of central India. It covers more than half of the forested area in the Terai landscape along the Himalayan foothills in Uttar pradesh, India. Although the species has wide geographical range and weather adaptability, it has been observed to shift towards the eastern region of India pertaining to the moisture richness in response to the climate change during early 21st Century (Chitale and Be-hera 2012).

Various studies have been carried out to study the Sal forests in Terai landscape of Uttar pradesh, most of which have highlighted that Sal forests are the most diverse and productive forests in India (Champion and Seth 1968; Hajra and Shukla 1983; Kumar *et al.* 2002). Sal forests occur as various communities/groups species based on the location, climatic conditions and interspeci-fic exchanges. The usual associate species of Sal in top canopy are: *Terminalia alata* W&A (asna), *Syzygium cumini* Linn Skeels (jamun), *Anogeissus latifolia* Wall. (Dhau) and *Adina cordifolia*

Hook. f. (haldu). A denser top canopy results in suppression of middle canopy. *Mallotus philippensis* Muell. arg. (rohini) can be found in abundance as middle storey species. The forest undergrowth comprise of *Ardisia solanacea* Roxb. (jalkaima), *Colebrookea oppositifolia* sn. (chapoha), *Clerodendron viscosum* Vent. (bhant), *Murraya koenigii* (kathnim). Dense growth of a liana, *Tiliacora acuminata* Lam Miers. (karvat) can be found in several patches in this forest. Shrubby undergrowth is dominated by semi-evergreen species, which is replaced by grasses as a consequence of burning. *S. robusta* remains leafless for a very short and varied period in Terai landscape, hence it makes difficult to identify and differentiate the species alone based on the spectral properties such as tone and texture. The classification may lead to confusion between mixed forests, Teak plantations and Sal forests; hence it is necessary to use satellite data at a temporal scale for precise identification and demarcation accounting the seasonal variations/ leaf phenology as well. *Shorea robusta* is used for various purposes ranging from construction activities to medicinal uses (AFT 2011). Sal is an important source of hardwood timber in India, with hard, coarse-grained wood. In India, Sal forests are harvested on a rotation cycle of 120 years, where thinning is applied every ten years, in line with standard practices (Tewari 1995). The mean annual volume increment is 4.9 m^3/ha (Negi 1984) and assumed mortality is 2% for the period of 20 years (Kaul et al. 2010).

The advancements in geospatial domain have made it amenable to use satellite datasets with higher spectral and spatial resolution as compared to the past. Higher spatial resolution provides an advantage of better vegetation mapping. The Terai landscape of Uttar Pradesh, India faces tremendous pressure due to anthropogenic and natural factors. The area is situated along the northern part of Uttar Pradesh and the lower boundary of Terai landscape lies in the alluvium rich western Gangetic plains, where the agricultural activities are intensively carried out throughout the year and the region ranks among the world's most densely populated areas (Johnsingh et al. 2004). The northern boundary of Terai landscape stretches along the Indo-Nepal border making it prone to human interference from the neighboring country. The forest corridor between protected areas in Terai landscape of India and Nepal was destroyed due to massive deforestation in the Nepal region. The cleared forested landscape was soon accommodated by human settlements and agricultural lands. The forested region of India along the Nepal border is thus exposed to human interference, grazing, poaching and results in decline in plant diversity and alterations in the ecosystem. In the present study we attempt to characterize various communities of *Shorea robusta* along the Himalayan foothills in Uttar Pradesh, India, based on the hybrid approach combining the satellite datasets and ground based inputs.

Materials and Methods

Study area

The study area ranges across 16 districts, from Saharanpur in the

northwest to Kushinagar located along the border of Bihar (Fig. 1). The Terai landscape, located in northern India, is listed among the most productive ecoregions of the world, well known for its vast biodiversity and high productivity (Kumar et al. 2002; De 2001). Alluvium rich soils of Terai coupled with an annual precipitation of over 1300 mm accommodate great diversity of vegetation. Sal is one of the dominant species in Terai landscape of Uttar Pradesh, which is extends in most of the districts of Terai. Various researchers have studied the vegetation pattern of terai landscape in India as well as in Nepal (Anon. 2011; Champion and Seth 1968; De 2001; Kumar et al. 2002; Sapkota et al. 2009; Timilsina et al. 2007). Kumar et al. (2002) analyzed the vegetation structure and diversity of dominant vegetation communities in Terai Arc Landscape extending from Uttarakhand to Bihar, while Shukla et al. (2009) analyzed the species diversity pattern in the Terai landscape. It has been clearly observed through the studies that Sal forests are the most productive and diverse forests of the region dominantly distributed in the Terai landscape of Uttar Pradesh, India. Previous studies have attempted the vegetation mapping in the Terai landscape of Uttar Pradesh; however they have some drawbacks such as the study was undertaken for a smaller area, the studies were either based on the field based inputs or based on the satellite datasets, the vegetation classification was attempted at broader scale with coarser resolution satellite datasets (Anon. 2011, Chauhan 2008, Chitale et al., 2012, Johnsingh 2004, Pandey and Shukla 2003).

**Fig. 1.** Location map of the study area

Community classification

The study deals with delineation, mapping and characterization of various Sal (*Shorea robusta*) communities in the Terai landscape of Uttar Pradesh, India based on the satellite datasets and field sampling inputs (Fig. 2). Two season (summer and winter) satellite imagery of Indian Remote Sensing (IRS)-P6 (Resourcesat-1) Linear Imaging Self Scanner (LISS-III) with 23.5m spatial resolution has been used for the community level classification.

Based on the spectral and spatial variations on the satellite imagery viz., size, shape, tone, texture, site and association, the *Shorea robusta* communities have been delineated and classified into nine different spectral classes (Fig. 3) using the interpretation key as shown in Table 1. Confusing forest types were verified on the ground based on the pre-field vegetation maps during the process of ground validation.

Table 1. Interpretation key and characteristics of Sal communities

Sr. No.	Sal Community	Champion and Seth (1968) Classification	Common associate species	Soil characteristics	Spectral properties
1	Siwalik	3C/2a	*Terminalia alata, Anogeissus latifolia*	Nahan sandstone with light soil	Bright red tone, coarse texture
2	Chandar	3C/C2/2d	*Syzygium cumini, Syzygium cerasoides*	Heavy alluvium (dry subsoil)	Dark brown to red tone, coarse texture
3	Damar	3C/C2/2b(ii)	*Syzygium cumini, Schleichera oleosa, Haldina cordifolia*	Loamy soils (without pebbles)	Bright red tone, smooth to medium texture
4	Dry plains	5B/C1/1b	*Terminalia alata, T. bellirica, Madhuca indica, Pterocarpus marsupium*	Top soil clayey, slow surface drainage	Red tone with blackish tinge, Coarse texture
5	Moist plains	3C/C2/2c	*Terminalia alata, T. bellirica, Lagerstroemia parviflora*	Light alluvium with dry subsoil	Bright to medium red tone, medium to smooth texture
6	Western alluvium plains	3C/C2/2d(i)	*Terminalia alata, Lagerstroemia parviflora*	Sandy alluvium (dry subsoil)	Medium red tone, smooth to medium texture
7	Eastern alluvium plains	3C/C2/2d	*Terminalia alata, Lagerstroemia parviflora, Dillenia pentagyna*	Yellow clayey alluvium	Dull to medium red tone, smooth to medium texture
8	Mixed moist deciduous	3C/C2/2c	*Mallotus phillipensis, Haldina cordifolia, Bauhinia retusa, B.variegata, Lagerstroemia parviflora, Dillenia pentagyna*	Clayey alluvium with wet subsoil	Bright to medium red tone, medium to coarse texture
9	Mixed dry deciduous	5B/C1/1b	*Terminalia alata, Pterocarpus marsupium, Madhuca indica, Acacia catechu*	Sandy alluvium (dry subsoil)	Light to medium red tone, coarse texture
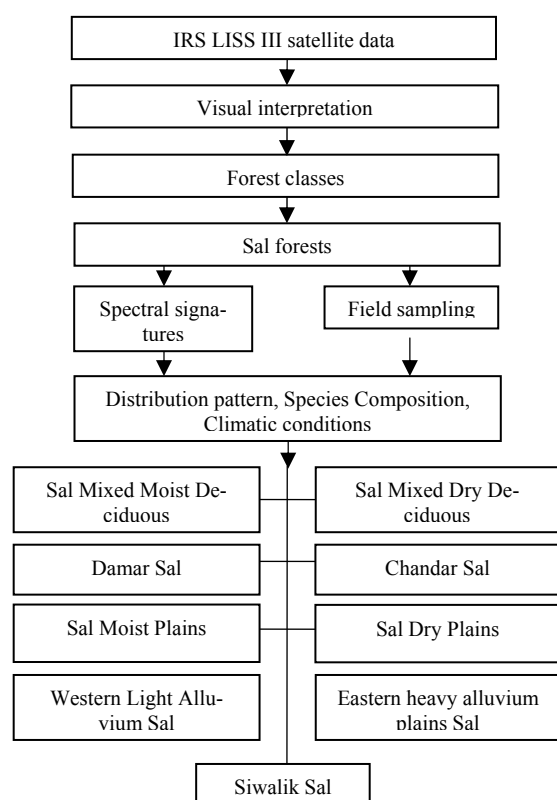
Fig. 2. Methodology flowchart
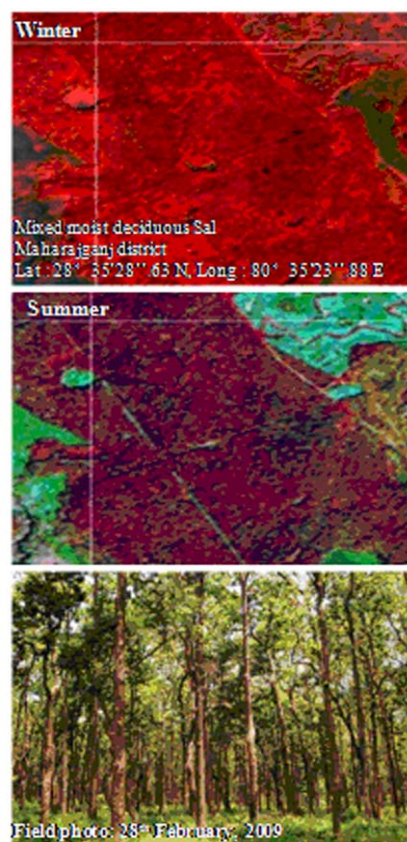
Fig. 3. Image chip containing summer and winter satellite data alongwith the field photograph of corresponding Sal community

Sampling method

Vegetation sampling was carried out in various Sal communities to account for the possible variations based on the distribution pattern, species composition and climatic conditions. During the field sampling a total of 65 plots were laid based on nested quadrate method i.e., 20 m × 20 m quadrate for trees, 5 m × 5 m for shrubs and 1 m × 1 m for herbs. For the tree species circumference at breast height (CBH) and height was recorded on a field performa, while for shrubs and herbs the number of individuals of each species was recorded. Other details such as the GPS location of corresponding sampling plots, date of sampling were also noted.

Data processing

The field data was arranged in the form of a database and phytosociological analysis was carried out to study the compositions and distribution of Sal forests. Finally based on the ground validation inputs, records from past studies and species composition, nine Sal communities were identified on the LISS III satellite data. The accuracy assessment of the vegetation mapping was performed based on the geographic locations of ground sampling plots.

Results

Shorea robusta is one of the major forest types in India and forms various communities based on the environmental factors, site specific attributes, species composition and associations with other communal plant species. In the present study, following nine communities of *Shorea robusta* have been characterized with greater than 80% accuracy; based the species composition, location, climatic conditions and spectral variations on the satellite datasets; *Chandar Sal*, *Damar Sal*, dry plains Sal, moist plains Sal, western light alluvium Sal, eastern heavy alluvium plains Sal, mixed moist deciduous Sal, mixed dry deciduous Sal and *Siwalik Sal* (Fig. 4). The total area covered by *Shorea robusta* (Sal) forests accommodating all nine communities in the Terai landscape was approximately 2256.77 km^2. It is evident from the area estimates that mixed moist deciduous Sal is the most dominant *Shorea robusta* community in the region covering approximately (1613.90 km^2), other major communities were mixed dry deciduous Sal covering 362.44 km^2, western alluvium plains Sal (298.71 km^2), dry plains Sal (108.71 km^2) and western light alluvium Sal (99.57 km^2). The nine communities have been described in detail as follows:
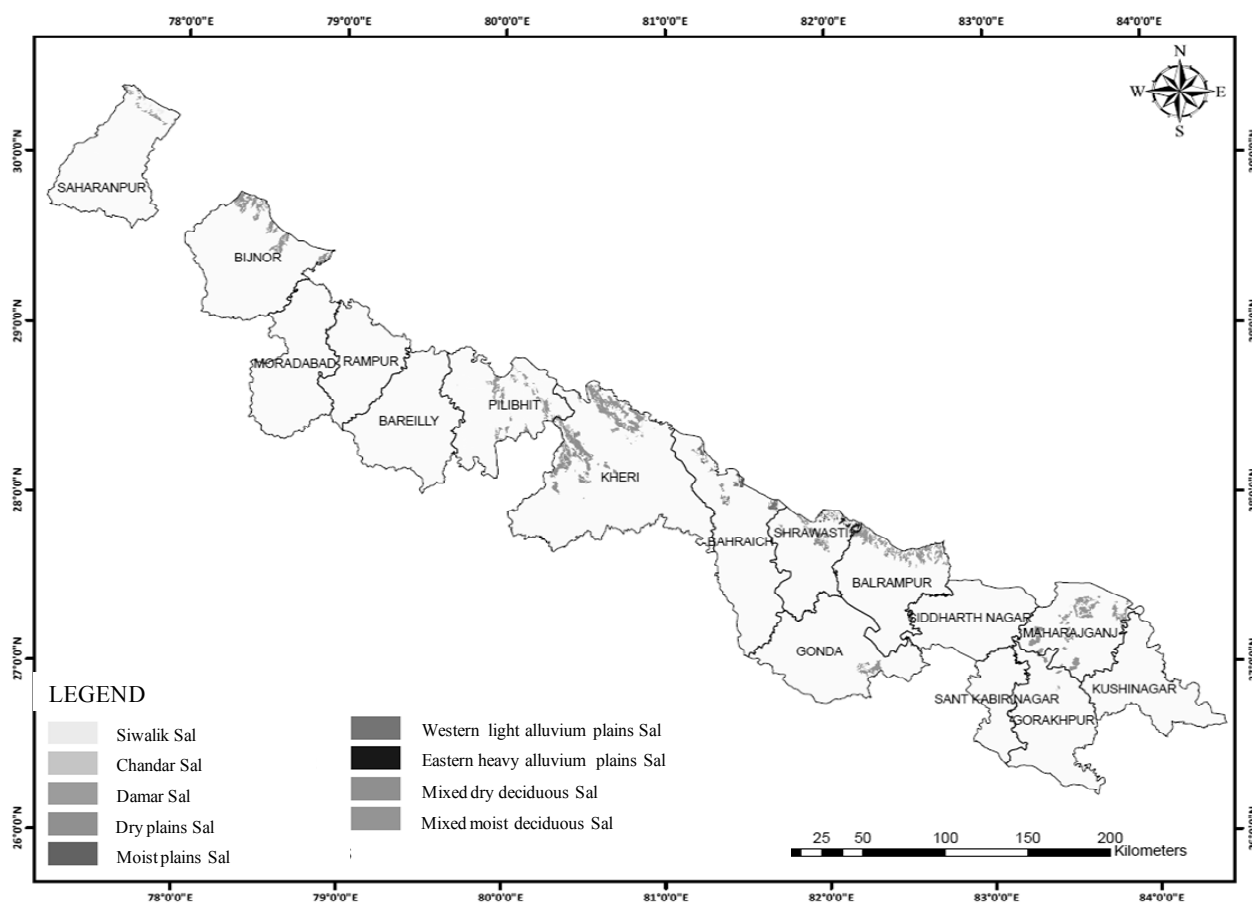

Fig. 4. Map showing nine Sal communities in Terai landscape of Uttar pradesh, India

Mixed moist deciduous Sal

As mentioned earlier this is the most dominant Sal community in the terai landscape, extending in almost all the Terai districts of Uttar Pradesh (Fig. 5) covering 1613.90 Km^2. As per the Champion and Seth (1968) classification this community could be classified as 3C/C2/2c, based on its physiographical and ecological attributes. In these forests, Sal exhibits more aggressive in natural gregarious habit, regeneration, and adaptation with the soil and climatic conditions than any of its associates and competitors. The mean annual temperature varies from 20–27°C, whereas the mean annual rainfall ranges from 1000–1500 mm. A large part of this forest occurs on clayey alluvium, mostly with wet subsoil. The semi-evergreen nature is the most important feature of Sal resulting in leafless condition of only 5–15 days on the onset of summer, which helps in identification of the forest on the satellite data. The forest shows bright to medium red tone in false colour composite (FCC) of the optical satellite data. Sal dominates the top canopy of these forests, along with these associates viz., *Terminalia alata* W&A (asna), *Syzygium cumini* Linn Skeels (jamun), *Anogeissus latifolia* Wall. (Dhau) and *Adina cordifolia* Hook. f. (haldu). A denser top canopy results in suppression of middle canopy. *Mallotus philippensis* Muell. arg. (rohini) can be found in abundance as middle storey species. The forest undergrowth comprised of *Ardisia solanacea* Roxb. (jalkaima), *Colebrookea oppositifolia* sn. (chapoha), *Clerodendron viscosum* Vent. (bhant), *Murraya koenigii* (kathnim). Dense growth of a liana, *Tiliacora acuminata* Lam Miers. (karvat) can be found in several patches in this forest. Shrubby undergrowth is dominated by semi-evergreen species, which is consequently replaced by grasses due to burning.

Chandar Sal

The Chandar Sal, which has been identified as a special type of savannah represented a sub-climax stretching across 13.47 Km^2. Frost is the chief limiting factor in Chandar Sal forests (De 2001). Frosty Chandars affect the growth of Sal forests, which results in partial growth of Sal at few places in terai region. The soil is light to very alluvium in nature on a dry sub-soil. Despite severe frost conditions, the Sal saplings have at many places managed to establish fairly. Chandars are mostly covered by tall coarse grasses and *Themeda arundinacea* (Roxb) Ridley (ula grass) (Johnsingh et al. 2004). This forest has been classified as 3C/C2/2d by Champion and Seth (1968) (Table 1). This forest can be found in patches in districts of Pilibhit, Kheri, Bahraich, Shrawasti, and Balrampur, dominantly in Dudhwa NP, Katarniyaghat WLS, Kishanpur WLS. The Chandar Sal can be identified on the satellite data based on their dark brown tone with a bluish tinge, coarse texture and regular pattern.

Damar Sal

Damar Sal community covered the area of 30.48 Km^2 and was found dominantly distributed in Kheri district along the northern side of the Sharda river (Fig. 4). *Damar* means higher alluvial terraces with loamy soils. The characteristic associate species of Damar Sal are *Adina cordifolia* Hook.f. (haldu) and *Schleichera oleosa* (kusum)*,* in top and middle canopies respectively, whereas *Tiliacora acuminata Lam* (Miers.) (karvat) was found as a dominant climber along with grasses like *Themeda arundinacea* (Roxb) *Ridley* (ula grass) and *Sclerotachya fusca* Roxb A. Camu (retva). As per the vegetation classification by Champion and Seth (1968), this community has been classified as 3C/C2/2b(ii) (Table 1). Bright to medium red tone, smooth texture and regular pattern helped the delineation of the Damar Sal forest on the satellite imagery.

Dry plains Sal

As the name indicates, dry plains Sal is located in the drier parts of *terai* covering 108.71 Km^2 and is often affected by the drought causing the deterioration of the Sal forests. The soil is dry and loamy alluvium. *Terminalia alata* W&A (asna) is one of the major associate species of *Shorea robusta* Gaertn. f. (Sal) in the top canopy. The middle canopy is formed by *Syzygium cumini (Linn) Skeels* (jamun), *Lagerstroemia parviflora* (Roxb.) (assidha), *Cassia fistula* (Linn.) (amaltas), *Mallotus philippensis* Muell. arg. (rohini), whereas the dominant shrubs and herbs include *Murraya koenigii* (Linn) Sprang.(Kathnim)*, Colebrookia oppositifolia* sn*.* (chapoha). During the rainy season the rate of water drain is low, which causes water logging in few regions. The percentage of Sal species is lesser than the other associate species. This *Shorea robusta* community can be classified as 5B/C1/1b (Champion and Seth 1968). Aegle forests can also be found distributed locally in Motipur, Kakraha ranges of Katarni-yaghat WLS, Bahraich. This forest type is found distributed locally in Saharanpur, Bijnore, and Pilibhit. The spectral signature of the dry plains Sal showed reddish tone with a black tinge and coarse texture on LISS-III satellite imagery (Table 1).

Moist plains Sal

As the name suggest, this type of forest ranges along the moist Indo-Gangetic alluvial plains of Uttar Pradesh. The type has been classified as 3C/C2/2c (Table 1) and further subdivided based on the levels of the alluvium in the soil.

Western alluvium plains Sal

It is mostly distributed in the parts of Kheri district, dominantly in the Dudhwa NP and Kishanpur WLS. This Sal community covered 298.71 Km^2 along the sandy alluvium with dry subsoil on lower levels in the bhabar and drier parts of the terai. The characteristic species other than Sal are *Terminalia tomentosa*, *Lagerstroemia parviflora* Roxb. (assidha), *Diospyrus tomentosa* Roxb. (tendu) in the top canopy and *Mallotus philippensis* Muell. arg. (rohini) being dominant in the middle canopy of the forest.

This forest can be classified as 3C/C2/2d(i) (Champion and Seth 1968).

Eastern heavy alluvium plains Sal

The eastern heavy alluvium plains Sal forest is distributed in the regions of Terai containing heavy alluvium soil along the eastern part of Uttar pradesh, mostly in Gorakhpur and Gonda districts. This Sal community covered approximately 99.57 Km^2 and has been classified as 3C/C2/2d by Champion and Seth (1968). The type is almost devoid of grasses with low undergrowth *Moghania chappar* with the dominant associate tree species like *Dillenia pentagyna* Roxb. (agay)*, Lagerstroemia parviflora* Roxb. (assidha), *Adina cordifolia* Hook.f. (haldu), *Syzygium cumini* Linn. Skeels (jamun)*, Mallotus philippensis* Muell. arg. (rohini)*, Clerodendrum viscosum* Vent. (bhant). This type of forest occurs on yellow clayey alluvium with enough small poles for coppice working.

Siwalik Sal

This type of forest is found in the region with Nahan sandstone and light soil, mostly distributed in the terai region. Siwalik Sal covered an area of approximately 28.71 km^2 and was dominantly distributed in the Saharanpur district. The forest composition was dominated by Sal species, but other species like *Lagerstroemia parviflora* Roxb. (asidha), *Adina cordifolia* Hook.f. (haldu). Siwalik Sal showed bright red tone and coarse texture in the IRS LISS III satellite imagery. This community has been classified as 3C/2a according to Champion and Seth forest classification (1968).

Discussion and conclusions

Terai landscape is listed among the important ecoregions of the world, well known for its unique BD and high productivity (Chitale et al 2012). The landscape is spread over 49,500 km^2 and accommodates diverse and highly productive tropical ecosystems. The Terai landscape in Uttar Pradesh is situated along the Indo-Nepal border and accommodates five wildlife protected areas. The landscape is under tremendous pressure due to natural as well as human induced disturbance factors. The landscape is situated between ever-expanding agricultural landscape of Uttar Pradesh on the southern side and that of Nepal along the northern side (Fig. 1). The floods and river course change along the alluvium rich region has caused massive forest destruction during the last few years, while the human interference for fire wood collection, animal grazing is causing ecosystem fragmentation and degradation. Although State forest department of Uttar Pradesh is putting extensive efforts to preserve these fragile ecosystems, proper forest conservation and monitoring efforts need to be implemented to counter further loss of biodiversity from the Terai landscape. *Shorea robusta* forests are dominantly distributed along the Terai landscape of Uttar Pradesh and accommodate diverse flora and fauna. Various researchers have studied

the vegetation of Terai landscape, however only some of them studied the *Shorea robusta* forests covering the whole Terai landscape (Champion and Seth 1968, De 2001, Johnsingh et al., 2004, Chauhan et al., 2008, Chitale et al., 2012). The studies indicated the current status of the forests through diversity, density, productivity, economic importance and climate sensitivity; but most of the studies were solely based on either the field datasets or satellite imagery and very few studies highlighted the declining ecological status of the *Shorea robusta* forests in the Terai landscape. Present study attempted the characterization of *Shorea robusta* communities along the Terai landscape in Uttar Pradesh, India; based on the moderate resolution satellite imagery and extensive ground inputs (Fig. 4). The Sal communities were classified based on the distribution pattern, species composition and climatic conditions (Table 1). Characterization of the *Shorea robusta* communities, attempted in the present study would give a perception about the distribution pattern, species composition, suitability of various soil types, and influence of the local climate variables on the forests, which could be advantageous for better conservation and monitoring of the forests based on the variable requirements.

Mixed moist deciduous Sal covered the highest area among all the Sal communities in the part of Indian Terai landscape. This indicates the suitability of physiographic and climate factors in the Terai landscape. The region is situated along the Himalayan foothills and exhibits higher moisture levels as compared to the other biogeographic zones of Uttar Pradesh viz., Gangetic plains and Semi-arid region. With the higher atmospheric moisture levels, the ecosystems are less vulnerable to the alterations in the phenology pertaining to the changes in climatic variables. Mixed dry deciduous Sal forest covered second largest area among the Sal communities. This Sal community showed lighter red tone as compared to mixed moist deciduous Sal forest, indicating sparsely arranged vegetation and lower moisture levels. The mixed dry deciduous Sal forest could be a step of ecological succession starting from mixed moist deciduous forest leading to savanna grassland. Dry plains Sal forest is distributed in Pilibhit, Kheri, Bahraich, Shrawasti and Balrampur districts. This community is situated along the clayey alluvium soils with slower surface drainage. Moist plains Sal covered an area of approximately 398.28 km^2 along the light alluvium with dry subsoil. The community can be further divided as eastern alluvium and western alluvium plains Sal respectively based on the soil type. The moist and dry plains Sal communities are only restricted along the alluvium plains in the Terai landscape, which are facing tremendous pressure due to expansion of agricultural lands in the alluvial tract. The human interference from both the sides of the Terai landscape has increased to the extent that the effects are now evident from the decline in diversity of the forests, fragmentation of the landscape as well as the human-wildlife conflicts in the region (Midha and Mathur 2010; Tripathi and Singh 2009).

Although the Sal forests showed dominant distribution throughout the landscape, the field reconnaissance data indicated the exploitation of these forests at many places along the Indo-Nepal border. The Sal forests are of immense ecological importance as they hold extensive ground flora and also support the

growth of associate species. The Sal forests are economically important, hence these are being damaged by surrounding human settlements through activities such as cattle grazing and collection of firewood from the forests. The effects of climate change can also be seen on the forested landscapes across the globe in the form of phenological shifts, forest fires, changes in the species associations and spread of invasive alien plant species (Ravindranath and Sukumar 1998; Parry et al. 2007). Efficient forest management policies need to be implemented in order to cope up with such consequences. The community level classification of the forests with the geographical extent and species associations would be useful for such activities.

Remote sensing proves to be advantageous over cost and time consuming field surveys and hence could be utilized for better mapping and monitoring of forest ecosystems (Turner et al. 2003; Lillesand et al. 2008). In the present study, a hybrid approach utilizing moderate resolution satellite datasets and ground based inputs has resulted in precise community level classification of Sal forests in the Terai landscape (Fig. 2). Previous studies in the region did not account for all the vegetation compositions, while most of the studies were carried out in a smaller area (Chauhan 2008, Pandey and Shukla 1999, 2003, Chitale et al. 2012). Few studies at larger area extent involved broad level vegetation mapping using coarse resolution satellite datasets (Johnsingh et al. 2004, Anon. 2011), which could not account for the community level variations in *Shorea robusta* forests. Although the present study was attempted with the aim of community level characterization of the *Shorea robusta* forests, the study requires more number of field sampling inputs to deal with the misclassified areas due to medium resolution data used in the study. Classification of *Shorea robusta* communities should be attempted in future, using higher temporal and spatial resolution to address the phenological events and improved characterization. The community level map of *Shorea robusta* forests could be beneficial as a baseline data for the future studies in the Terai landscape of Uttar Pradesh and would also be advantageous for better forest conservation and management activities. The future work may involve species level forest classification utilizing high resolution satellite data at temporal scales to account for the phenological as well structural changes in the forests.

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